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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

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CONCLUDING REPORT ON FREE-SPINNING AND RECOVERY CHARACTERISTICS OF A 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

TED NO. NACA AD 395

By James S. Bowman, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

AUG 14 1956

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CONCLUDING REPORT ON FREE-SPINNING AND RECOVERY CHARACTERISTICS OF A 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

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SUMMARY

An investigation has been completed in the Langley 20-foot free-spinning tunnel on a 1/24-scale model of the Grumman F11F-1 airplane to determine its spin and recovery characteristics. An interim report, Research Memorandum SL55G20, was published earlier and the present report concludes the presentation of results of the investigation. Primarily, the present report presents results obtained with engine gyroscopic moments simulated on the model. Also, the current results were obtained with a revised larger vertical tail recently incorporated on the airplane.

It was difficult to obtain developed spins on the model when the spin direction was in the same sense as that of the engine rotation (right spin on the airplane). The developed spins obtained were very oscillatory and the recoveries were unsatisfactory. These results were similar to those previously reported for which engine rotation was not simulated. When the spin direction was in the opposite sense (left spin on the airplane), however, developed spins were readily obtainable. Recoveries from these spins also were unsatisfactory. Satisfactory recoveries were obtained on the model, however, when rudder reversal was accompanied by extension of small canards near the nose of the airplane or by deflection of the horizontal tail differentially with the spin.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/24-scale model to determine the spin and recovery characteristics of the Grumman F11F-1 airplane.

The present report presents the test results obtained with the engine gyroscopic moments simulated and with a larger revised vertical tail incorporated on the airplane (see fig. 1) since the tests of reference 1. All tests were conducted for erect spins for the landing loading and for the most rearward center of gravity located at 29.9 percent $\bar{c}$. Although the landing loading was used for the model tests, it is felt that the results obtained are also representative of what would be obtained at the flight loading. As indicated in reference 1, model spin tests conducted for the rearward center-of-gravity position indicated that the model spin was similar to that of the normal center-of-gravity position except that the duration of the spin was longer. For this reason, all the present tests were conducted for the rearward center-of-gravity position. Previous results of erect and inverted spin tests and tests to determine the size parachute required for emergency spin recovery are presented in reference 1.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations of model mass characteristics occurring during tests, and a general comparison between model and airplane results.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug/cu ft

μ relative density of airplane, $\frac{m}{\rho Sb}$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

V full-scale true rate of descent, ft/sec

Ω full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

A 1/24-scale model of the Grumman F11F-1 airplane was furnished by the Bureau of Aeronautics, Department of the Navy, and was checked for dimensional accuracy and prepared for testing by the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model as tested is shown in figure 1.

Lateral control is obtained on the F11F-1 airplane by upper-surface slotted spoilers (flaperons) instead of ailerons (fig. 1). Previous tests conducted on this model (ref. 1) indicated that the flaperons had very little or no effect on the spin and recovery characteristics and were therefore at zero deflection for all test results presented in this report. The trim tabs on the wing tips were not used for these tests and were set for zero deflection throughout this investigation. The horizontal tail is an all-movable type with elevators. However, the elevators operate only when the flaps are down. The elevators were set for zero deflection for all tests. The horizontal tail was made to operate differentially for use as lateral controls for some of the tests. Deflection of the horizontal tail for lateral control was considered to be independent to the deflections for longitudinal control. The wing fences were not used in the current tests in order to facilitate testing, inasmuch as reference 1 indicated little effect on spin and recoveries. All tests were conducted with the model in the clean condition. Brief tests were also conducted with the leading-edge slats extended.

A photograph showing the model in the normal flying configuration with leading-edge slats extended is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). The mass characteristics and inertia parameters for loadings possible on the airplane and for the loading tested on the model are indicated in table II.

Spin tests conducted simulated both engine off and on. All spin-recovery results obtained by rudder reversal with the model in the clean condition and simulating engine on are presented for engine angular momentums of idle and maximum rotational speed. The spin recoveries made with canards and with differentially operated horizontal tails and all tests conducted with leading-edge slats extended are presented for engine off and for an engine angular momentum simulating only the idle rotational speed.

The angular momentum of the rotating parts of the full-scale Pratt & Whitney J57 jet engine was simulated by rotating a flywheel with a small direct-current motor powered by small silver-cell batteries. The flywheel was located in the model so that the axis of the angular momentum was parallel to the longitudinal axis of the airplane.

The F11F-1 airplane originally had maximum rudder deflection of $\pm 25^\circ$. However, late in the model spin-test program, the rudder deflection for the airplane was decreased and additional model tests were conducted to evaluate the revised rudder deflections.

The maximum control deflections (measured perpendicular to the hinge lines) used on the model during tests were:

Rudder:
- Original, deg . . . . 25 right, 25 left
- Revised, deg . . . . 6 right, 6 left

Horizontal tail (for longitudinal control):
Leading edge down, deg 18
Leading edge up, deg 5

Horizontal tail (for lateral control):
Leading edge down, deg 15
Leading edge up, deg 15

RESULTS AND DISCUSSION

The results of model tests are presented in charts 1 through 11 and in table III. The model data are presented in terms of full-scale values for the airplane at an altitude of 25,000 feet. All spins, except the spins with leading-edge slats extended, were similar to the right and left when the engine angular momentum was not simulated and are arbitrarily presented in terms of right spins. However, the spins presented with the engine rotation in the same and opposite sense to spin direction simulate right and left spins, respectively, on the airplane. The tests conducted with the leading-edge slats extended are presented for both right and left spins.

Model spin-test results indicate that the spinning characteristics of the F11F-1 airplane can be affected appreciably by the gyroscopic moments of the jet engine (for example, charts 1 and 2). Previous tests conducted to determine the effects of the engine angular momentum on the spinning characteristics of a model (ref. 2) indicate that for a right-hand rotating engine the model will spin steeper and rotate faster to the right and will spin flatter and rotate slower to the left than when no engine rotation was simulated. For the F11F-1 model when spin rotation and engine rotation were in the same sense (simulating a right spin on the airplane and a right-hand rotating engine), the results obtained were similar to those obtained when no engine rotation was simulated, which in turn were generally similar to corresponding test results reported in reference 1. Spins could not be obtained unless the horizontal tail was full up (stick back). The developed spins obtained were very oscillatory and of short duration; that is, the model oscillated out of the spin after a few turns in the spin. The recoveries from the developed spin were slow and unsatisfactory.

When the model spin and engine rotation were in opposite senses (simulating a left spin on the airplane and a right-hand rotating engine), spins were obtained for all horizontal-tail positions (up, neutral, and down). The spins were very oscillatory in roll and yaw and recoveries were unsatisfactory.

Results obtained simulating the idle and maximum speeds of the engine (charts 2 and 3, respectively) indicated little or no difference in the spinning characteristics of the model because of the difference in engine speed.

Alternate recovery methods were tried by using extendible canard surfaces near the nose and by using differentially operated horizontal tails. The results of these tests are presented in charts 4 and 5. These tests were conducted simulating no engine rotation and simulating spins with the engine turning at idle rotational speed in the same sense and in the opposite sense as the spin rotation. Results indicated satisfactory recoveries by reversing the rudder against the spin and simultaneously extending the canards. The extension of canards alone was not satisfactory. The size and position of canards used for these tests are shown in figure 3.

A detailed analysis on the effectiveness of canards for spin recovery is presented in reference 3. Experience has indicated that the yawing moment is the most important moment affecting the spin recovery and, as shown in reference 3, if the canards are placed near the nose of the airplane and if the spin axis is originally at or near the center of gravity, the extended canards will produce an antispin yawing moment provided the canards are hinged high on the fuselage.

Recoveries by reversing the rudder against the spin combined with simultaneous movement of the horizontal tail differentially with the spin were satisfactory. These results indicate that if the horizontal tail is used to provide a rolling moment with the spin (rolling moment to right for right spin) in conjunction with rudder reversal, satisfactory recoveries can be obtained. Test results indicated that when only the horizontal tail was deflected differentially for recovery, recoveries were not quite satisfactory and that for satisfactory results rudder reversal should accompany the differential horizontal tail movement.

The tests conducted with leading-edge slats extended are presented in charts 6 to 9. The difference in right and left spins is probably due to some asymmetry in the slats. However, these results still indicated generally unsatisfactory recovery characteristics but extension of leading-edge slats did provide a favorable effect. Recoveries attempted from the right spins by rudder reversal (charts 6 and 7) are no worse than, and in some instances better than, the recoveries by rudder reversal from similar spins with slats retracted (charts 1 and 2).

The extension of slats indicated a more powerful effect on the spin characteristics when left spins were attempted (charts 8 and 9). No spins were obtained except when engine rotation in the opposite sense to the spin (left spin on the airplane) was simulated. The recoveries from this spin by rudder reversal were satisfactory. In view of the fact that the leading-edge slats may assist in some instances in providing better recoveries, it is recommended that the slats be extended during the spin to take advantage of any benefit they may offer.

Additional tests were conducted on the model to determine the effects on the spin and recovery characteristics due to the decreased maximum rudder deflection on the airplane from 25° to 6°. The results of these tests are presented in charts 10 and 11 and table III. In chart 10 are presented the results obtained with the engine gyroscopic moment not simulated and in chart 11 the results for the engine moment simulated with flywheel rotation in the same and opposite sense to the spin are presented. All recovery attempts on charts 10 and 11 are by rudder reversal alone. A comparison of charts 1 and 2 with charts 10 and 11 indicates that there is no appreciable difference in the spin and recovery characteristics due to the decreased rudder deflection and that the recoveries by rudder reversal are still unsatisfactory.

The results presented in table III include spins with slats extended with recoveries by rudder reversal and spins with slats retracted with recoveries by rudder reversal accompanied by simultaneous movement of the horizontal tail from full up to 20° down and by simultaneous extension of canard surfaces near the nose.

The results of table III obtained with the leading-edge slats extended compare in general with the results obtained in charts 6 to 9. The recoveries obtained by full rudder reversal for the spins with the flywheel rotating in the opposite sense to the spin were much slower for the decreased rudder deflection than for the original rudder deflection of ±25°.

The results obtained for full rudder reversal and simultaneous extension of canards (table III) compare with the results obtained with full rudder reversal and simultaneous extension of canards of charts 4 and 5 (for original rudder deflection of ±25°). The effectiveness of the canards was, therefore, not reduced by decreasing the maximum rudder deflection.

The effect of moving the stick full forward in conjunction with moving the rudder to full against the spin may be seen from the results obtained in table III. These results were obtained by moving the rudder to 6° against the spin and simultaneous movement of the horizontal tail from full up (stick full back) to 20° down instead of the normal maximum travel of 5° down (stick forward). These results indicate that even though forward movement of the stick is not good enough for satisfactory recovery, movement of the stick full forward after rudder reversal may expedite the recovery.

CONCLUSIONS

The following conclusions regarding the spin and recovery characteristics of the airplane at an altitude of 25,000 feet are made and are based on test results of a 1/24-scale model of the Grumman F11F-1 airplane:

1. It may be difficult to obtain a developed spin for this airplane when the engine rotation is in the same sense as the spin rotation (right spin for a right-hand rotating engine). Developed spins should be readily obtainable when the engine rotation is in the opposite sense to the spin rotation (left spin for a right-hand rotating engine). Any developed erect spin obtained will be oscillatory in roll and yaw, and it may be difficult to obtain recovery.

2. Extension of the leading-edge slats may assist in some instances in providing faster recoveries and, therefore, they should be extended to take advantage of any benefit they may offer.

3. Recoveries can be made satisfactory by extending properly located canard surfaces near the nose and simultaneously reversing the rudder against the spin.

4. The horizontal tail can be used advantageously for recoveries if it is made to operate differentially. Satisfactory recoveries can be obtained by deflecting the horizontal tail differentially to provide a pro-spin rolling moment simultaneously with movement of the rudder against the spin.

5. Movement of the stick full forward after rudder reversal was not good enough for satisfactory recovery but may expedite the recovery.

6. Decreasing the maximum rudder deflection from 25° to 6° had no appreciable effect on the spin and recovery characteristics.

7. Increasing the vertical-tail area had no appreciable effect on the spin and recovery characteristics.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 18, 1956.

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APPENDIX

TESTING TECHNIQUE AND MODEL PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to the Langley 15-foot free-spinning tunnel described in reference 4 except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising airstream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 4.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 5, 6, and 7). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved for recovery until the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, > 300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it was still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as > 3. A > 3-turn recovery, however, does not necessarily indicate an improvement over a > 7-turn recovery. A recovery of 10 or more turns is indicated by ∞. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	± 1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery obtained from motion-picture records	$\pm\frac{1}{4}$
Turns for recovery obtained visually	$\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of ±1°.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight, mass distribution, and the simulated angular momentum of the F11F-1 model varied from the true scaled-down values within the following limits:

Weight, percent	1 high
Center-of-gravity location, percent $\bar{c}$	2 forward to 1 rearward
Angular momentum, percent	12 high to 12 low

Moments of inertia:

I_X, percent	1 to 4 high
I_Y, percent	1 to 5 high
I_Z, percent	0 to 3 high

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 8 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that for the remaining 10 percent of the time the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 8 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, although the higher rate of descent was found to be generally associated with the smaller angle of attack regardless of whether it was for the model or the airplane.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE GRUMMAN F11F-1 AIRPLANE CORRESPONDING TO THE 1/24-SCALE MODEL INVESTIGATED

Overall length, ft	42.83
Wing:	
Overall span, ft	31.63
Folded span, ft	27.33
Area (exclusive of leading-edge extension), sq ft	250
Mean aerodynamic chord, in.	98.38
Location of leading edge of $\bar{c}$ with respect to fuselage station 0, in.	248.08
Airfoil section:	
Root	NACA 65A006 (Modified)
Tip	NACA 65A004 (Modified)
Sweepback at 0.25-chord line, deg	35
Incidence, deg	0
Dihedral, deg	-2.5
Aspect ratio	4.0
Taper ratio	0.50
Flaperons:	
Area, sq ft	21.3
Span (perpendicular to fuselage center line), percent b/2	61.7
Trailing edge, percent wing chord	84
Hinge, percent wing chord	70
Trimmers:	
Area, sq ft	2.1
Location (from plane of symmetry), in.	
Root	163
Tip	Wing tip
Hinge line, from fuselage station 0, in.	375.41
Travel:	
Up, deg	5
Down, deg	5
Leading-edge slats:	
Location (from plane of symmetry), in.	
Inboard	75
Outboard	Wing tip
Chord, percent wing chord:	
Root	10
Tip	10
Travel:	
Down, deg	20

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

GRUMMAN F11F-1 AIRPLANE CORRESPONDING TO THE 1/24-SCALE

MODEL INVESTIGATED - Concluded

Flaps:	
Type	Slotted
Span, ft	11.06
Leading edge, percent wing chord	80
Trailing edge, percent wing chord	100
Hinge line, percent wing chord	83.3
Travel:	
Up, deg	0
Down, deg	40
Fence:	
Total area, sq ft	5.128
Location (from plane of symmetry), in.	75
Horizontal tail:	
Airfoil section (parallel to fuselage center line):	
Root	NACA 65A006
Tip	NACA 65A004
Area, sq ft	65.5
Span, ft	15.17
Sweep at 25 percent chord, deg	35
Aspect ratio	3.5
Taper ratio	0.4
Elevator (operative only when flaps are down):	
Area, sq ft	10.9
Hinge line, percent horizontal tail chord	75
Travel, moves down only (measured from plane of horizontal tail), deg:	
When horizontal tail is 0°	1
When horizontal tail is -8°	6.5
When horizontal tail is -15°	19.3
When horizontal tail is -18°	30
Vertical tail:	
Total area (exposed), sq ft	45.1
Airfoil section:	
Root	NACA 16-005.625
Tip	NACA 16-005.625
Rudder:	
Area, sq ft	7.36

[redacted]

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE GRUMMAN F11F-1 AIRPLANE AND FOR THE LOADING TESTED ON THE 1/24-SCALE MODEL

[Model values given are converted to full-scale; moments of inertia are given about the center of gra

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass p	
		$x/\bar{c}$	$z/\bar{c}$	Sea level	25,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	I_Y
Airplane values										
Catapult	19,500	0.2568	0.0373	32.21	71.93	11,003	36,097	45,085	-414×10^{-4}	-148
Flight (normal c.g.)	16,500	0.2432	0.0321	27.26	60.86	6,240	34,894	39,335	-559	-87
Flight (most forward c.g.)	16,500	0.2401	0.0325	27.26	60.86	6,239	34,887	39,327	-559	-87
Flight (most aft c.g.)	16,500	0.2901	0.0328	27.26	60.86	6,251	34,862	39,341	-558	-87
Landing	14,100	0.2400	0.0414	23.29	52.01	6,066	30,911	35,407	-567	-103
Model values										
Landing loading (most aft c.g.)	14,284	0.283	0.0163	23.62	52.74	6,289	32,337	36,477	-587×10^{-4}	-93

TABLE III.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF A 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; recovery attempted from, and steady-spin data presented for, rudder full with spins; recoveries attempted by indicated control movement; model values converted to corresponding full-scale values; maximum rudder deflection ±6°]

Control settings for spin	Control manipulation for recovery	Direction of spin	Slats	Flywheel		α, deg (a)	ϕ, deg (a)	V, fps	Ω, rps
				Rotational speed	Direction				
Horizontal-tail trailing edge up, lateral controls neutral	Rudder[b]	Right	Extended	0	---------	50 77	32U 28D	271	0.19
	Rudder[b]	Right	Extended	Idle	Opposite sense to spin	---	---	257	---
	Rudder[b]	Left	Extended	Idle	Opposite sense to spin	---	---	---	---
	Rudder and canards[d]	Right	Closed	0	---------	47 79	21U 29D	271	0.22
	Rudder and canards[d]	Right	Closed	Idle	Opposite sense to spin	55 79	9U 8D	271	0.16
	Rudder and horizontal tail[e]	Right	Closed	0	---------	57 82	24U 44D	271	0.23
	Rudder and horizontal tail[e]	Right	Closed	Idle	Opposite sense to spin	55 79	9U 8D	271	0.16
	Rudder and horizontal tail[e]	Right[h]	Closed	Idle	Same sense as spin	54 74	34U 27D	301	0.23

[a]Oscillatory spin, range of values given. (U indicates inner wing up; D indicates inner wing down.)

[b]Recovery attempted by rudder reversal to full against the spin.

[c]Entered a glide.

[d]Recovery attempted by rudder reversal to full against the spin and simultaneously extending the canards.

[e]Recovery attempted by rudder reversal to full against the spin and simultaneously moving the horizontal tail from full up to

[f]Recovered in an inverted glide.

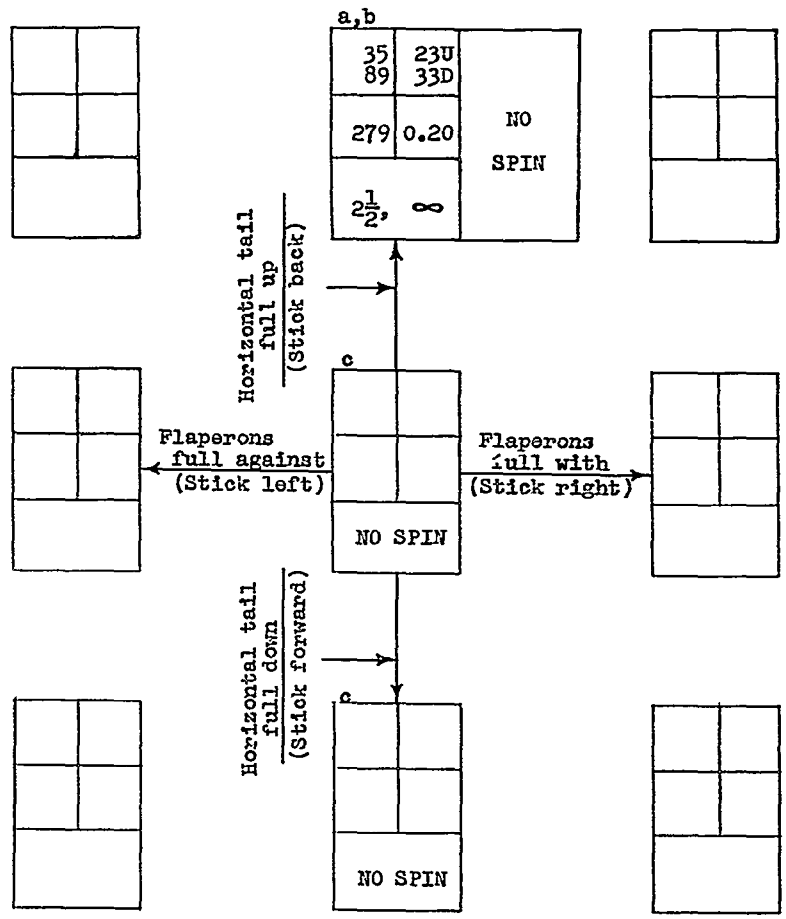
[g]Recovered in a glide, rolling about Y-axis.

[h]For this condition, a spin and a no-spin condition were obtained.

[i]Recovered in a dive.

CHART 1.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spins; recovery attempted by rapid full rudder reversal; angular momentum not simulated; maximum rudder deflection ±25°]



[a]Oscillatory in roll and yaw, range of values given.
[b]Two conditions possible.
[c]Entered an inverted dive, occasionally rolling about X-axis.

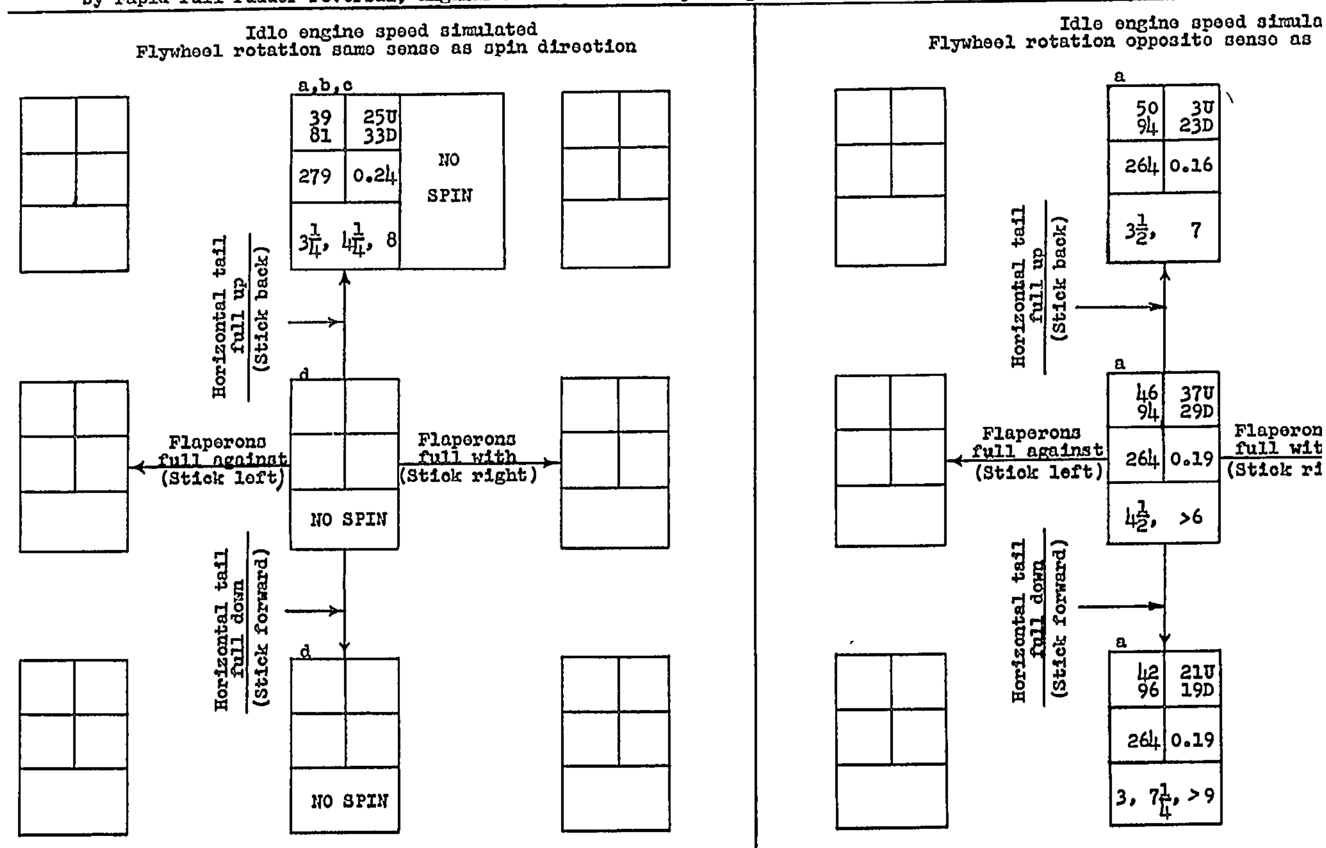
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[redacted]

CHART 2.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLA

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spin by rapid full rudder reversal; angular momentum of the jet engine simulated as indicated; maximum rudder deflectio

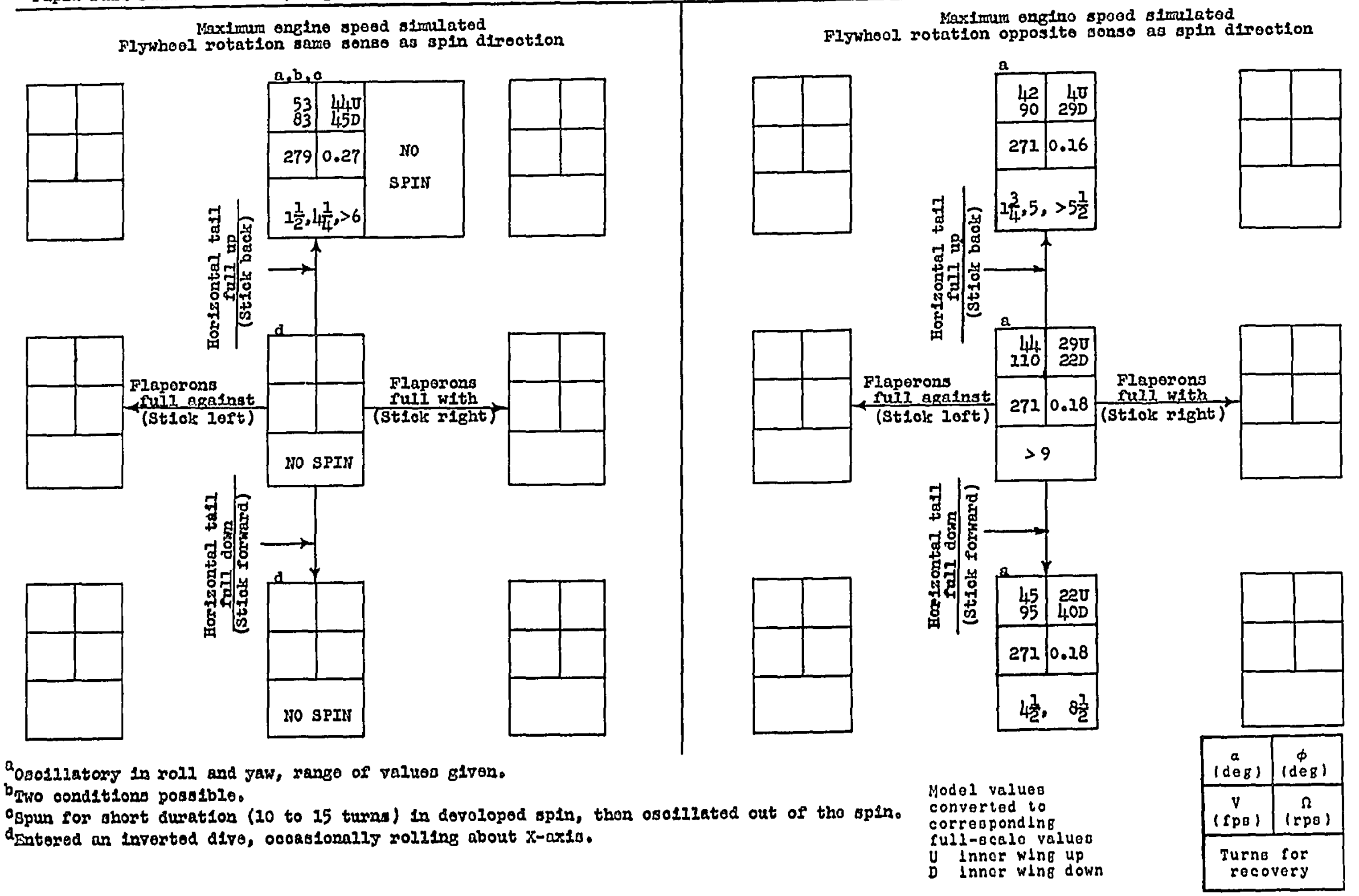


[a]Oscillatory in roll and yaw, range of values given.
[b]Two conditions possible.
[c]Spun for short duration (10 to 15 turns) in developed spin, then oscillated out of the spin.
[d]Entered an inverted dive, occasionally rolling about X-axis.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 3.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spins; recovery attempted by rapid full rudder reversal; angular momentum of the jet engine simulated as indicated; maximum rudder deflection ±25°]

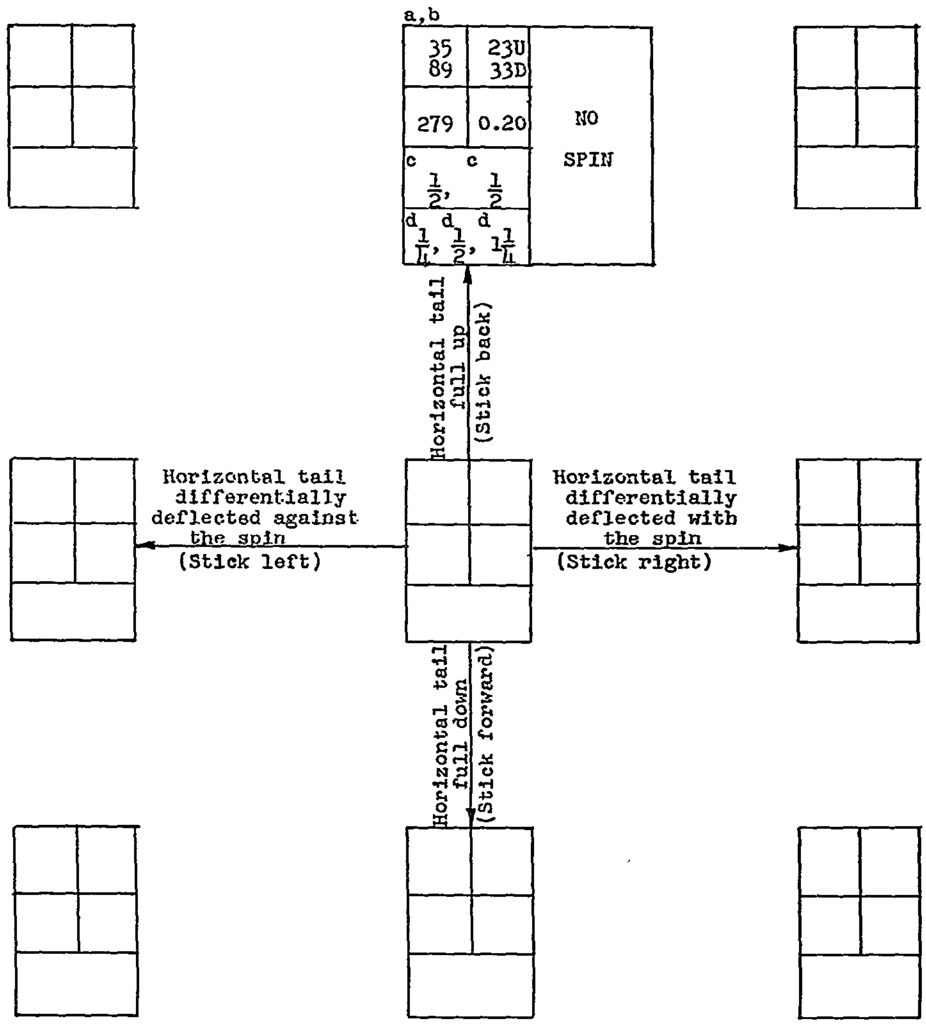


[a] Oscillatory in roll and yaw, range of values given.
[b] Two conditions possible.
[c] Spun for short duration (10 to 15 turns) in developed spin, then oscillated out of the spin.
[d] Entered an inverted dive, occasionally rolling about X-axis.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

CHART 4.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spins; recovery attempted as indicated; angular momentum not simulated; maximum rudder deflection ±25°]



[a]Oscillatory in roll and yaw, range of values given.

[b]Two conditions possible.

[c]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and deflecting the horizontal tail differentially from laterally neutral to $\frac{2}{3}$ with the spin.

[d]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and extending canards.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

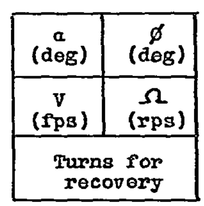
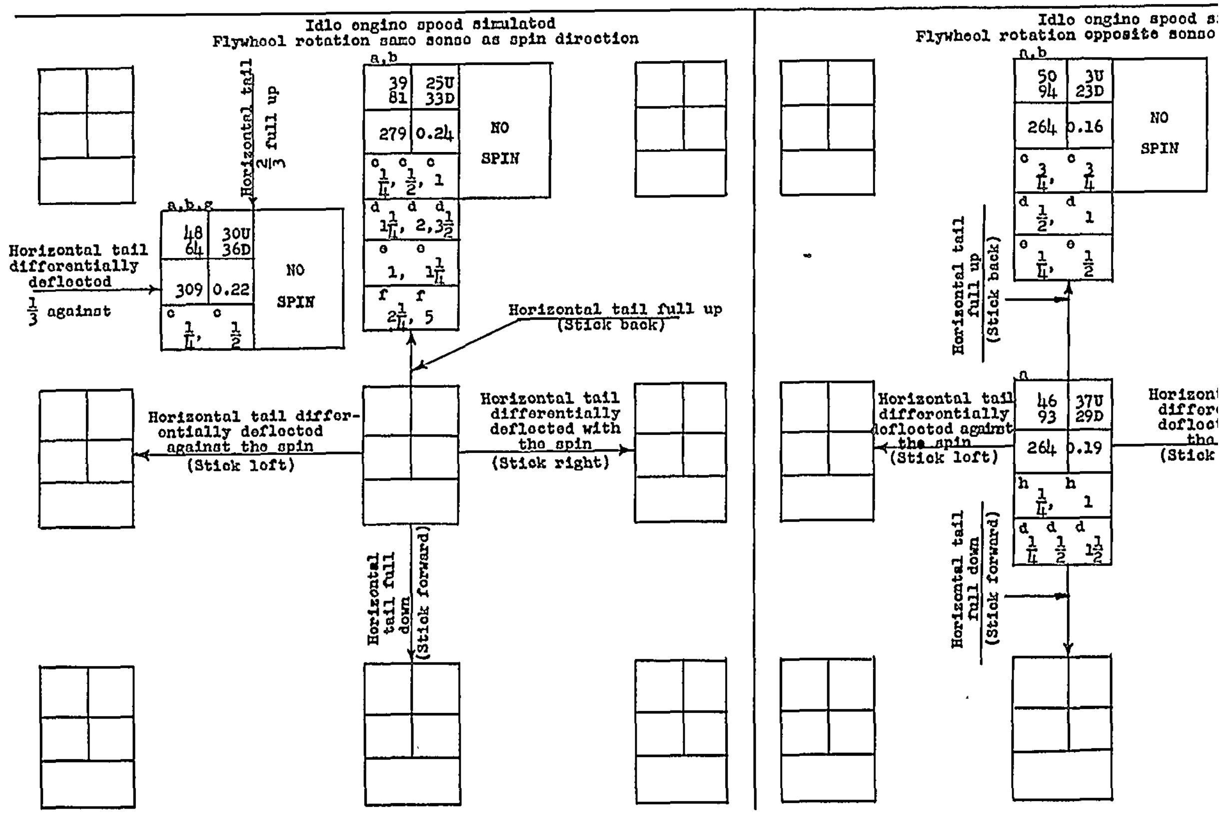


CHART 5.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLAN

[Landing loading; slats retracted; recovery attempted from and steady-spin data presented for, rudder full with spins; recov indicated; angular momentum of the jet engine simulated as indicated; maximum rudder deflection ±25°]



[a]Oscillatory in roll and yaw, range of values given.

[b]Two conditions possible.

[c]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and deflecting the horizontal tail differentially from laterally neutral to $\frac{2}{3}$ with the spin.

[d]Recovery attempted by deflecting the horizontal tail differentially from laterally neutral to full with the spin.

[e]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and extending the canards.

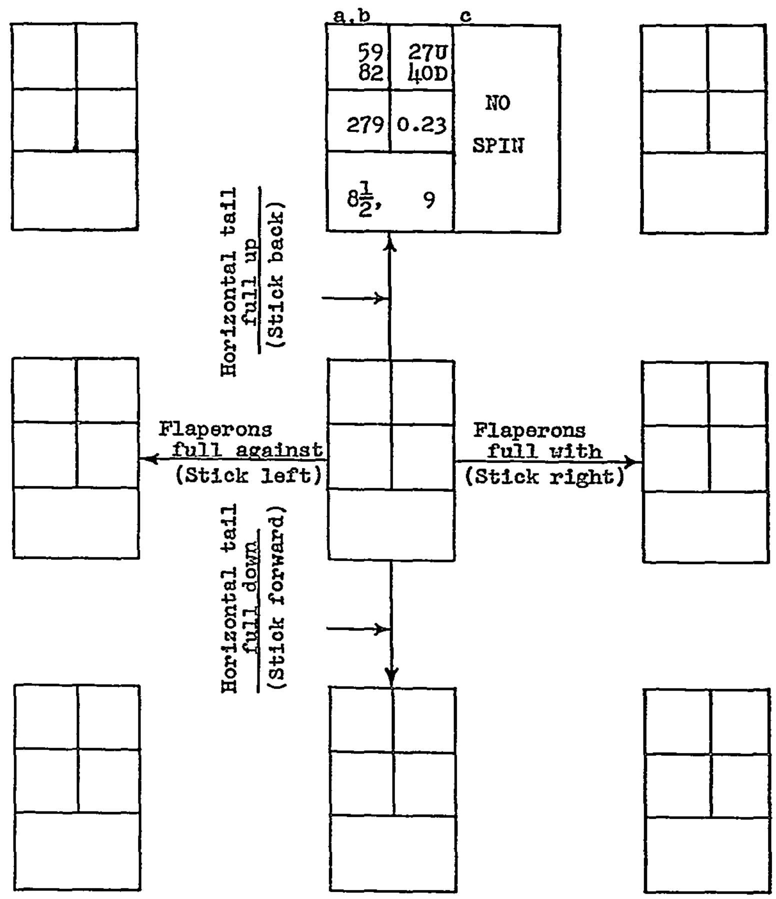
[f]Recovery attempted by extending canards alone.

[g]Spun for short duration (10 to 15 turns) in developed spin, then oscillated out of the spin.

[h]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and the horizontal tail differentially to with the spin.

CHART 6.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats extended; recovery attempted from, and steady-spin data presented for; rudder full with spins; recovery attempted by rapid full rudder reversal; angular momentum not simulated; maximum rudder deflection 25°]



[a]Oscillatory spin, range of values given.
[b]Two conditions possible.
[c]Entered a dive.

Model values converted to corresponding full-scale values.
U inner wing
D inner down

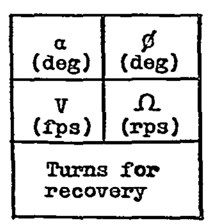
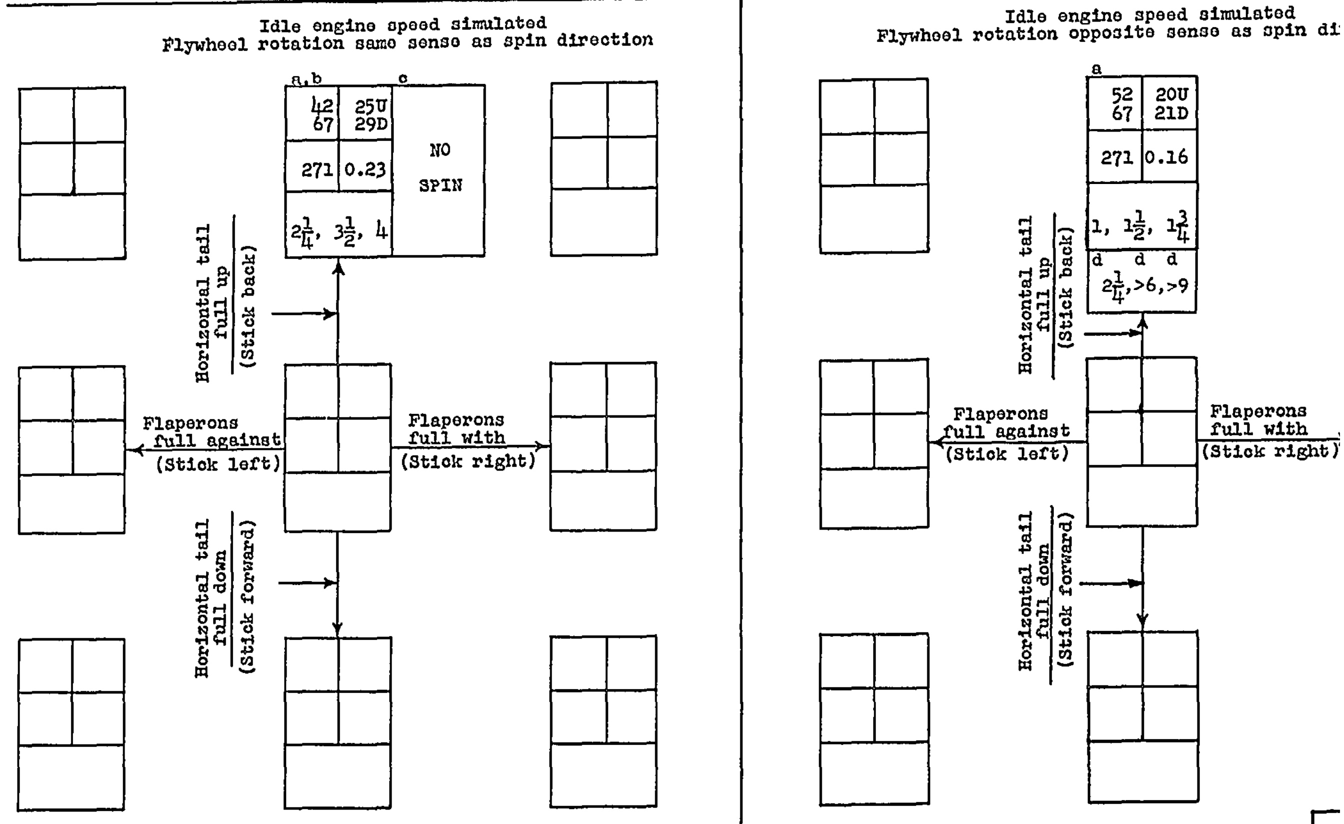


CHART 7.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats extended; recovery attempted from, and steady-spin data presented for, rudder full with spins; recover rapid full rudder reversal or as otherwise indicated; angular momentum of the jet engine simulated as indicated; maximum ru

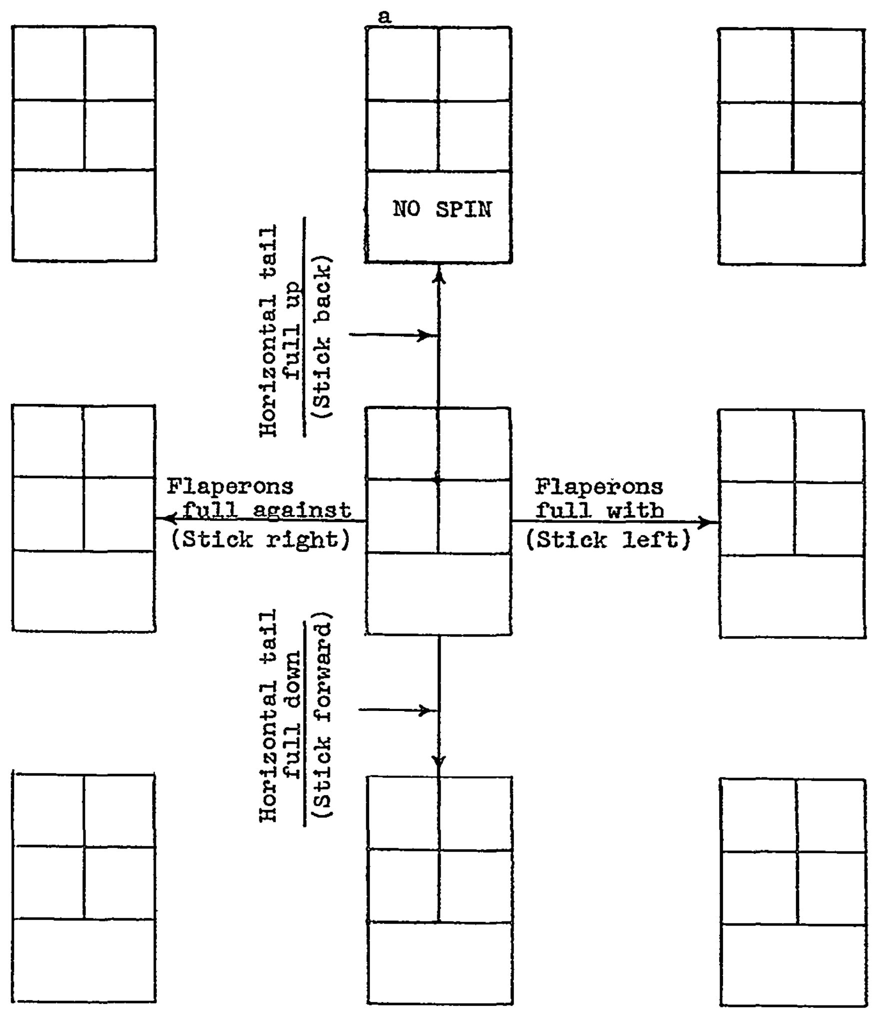


[a]Oscillatory spin, range of values given.
[b]Two conditions possible.
[c]Entered a dive.
[d]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

CHART 8.- LEFT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

Landing loading; slats extended; recovery attempted from, and steady-spin data presented for, rudder full with spins; recovery attempted by rapid full rudder reversal; angular momentum not simulated; maximum rudder deflection $\pm 25^\circ$



[a]Entered a glide.

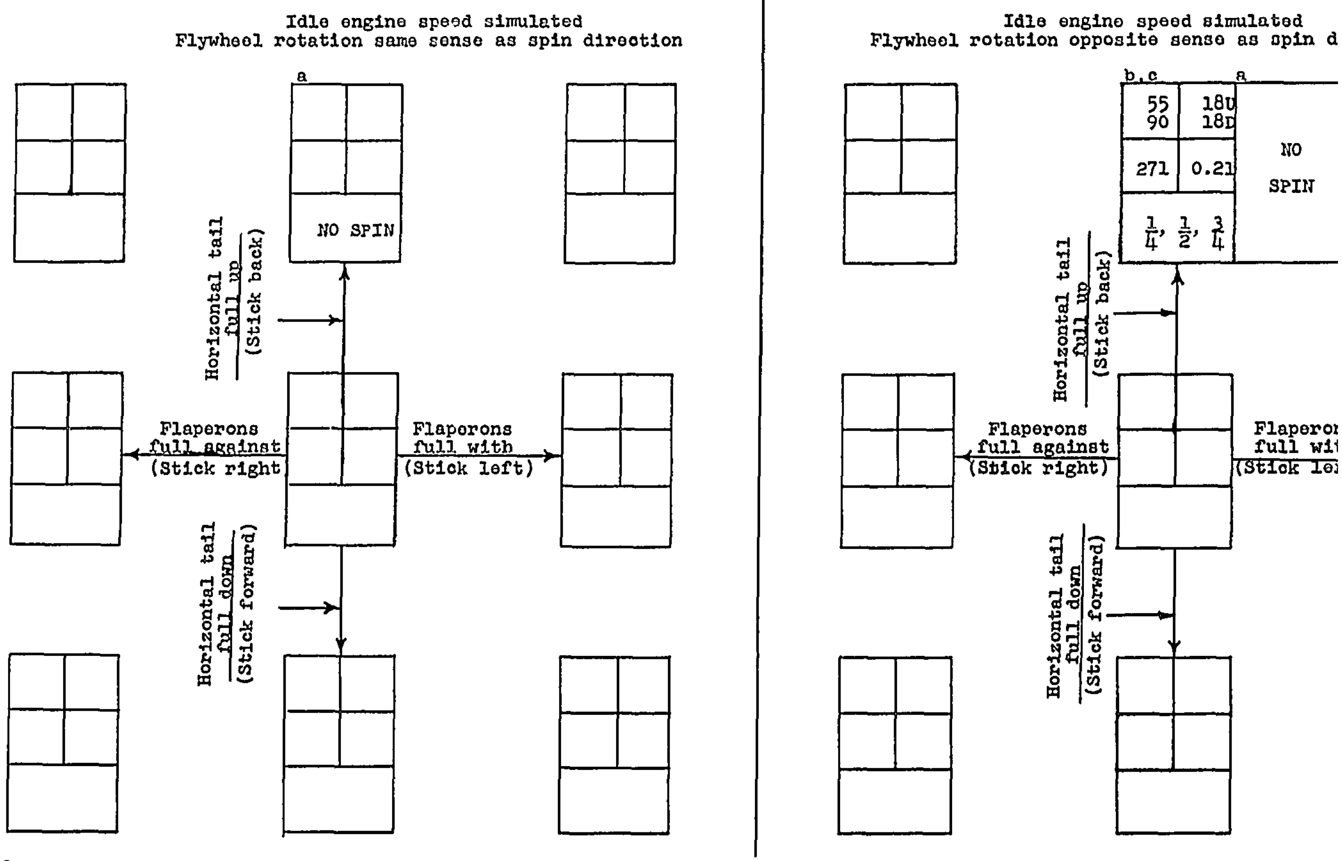
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[redacted]

CHART 9.- LEFT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLA

[Landing loading; slats extended; recovery attempted from, and steady-spin data presented for, rudder full with spin
by rapid full rudder reversal; angular momentum of the jet engine simulated as indicated; maximum rudder deflecti

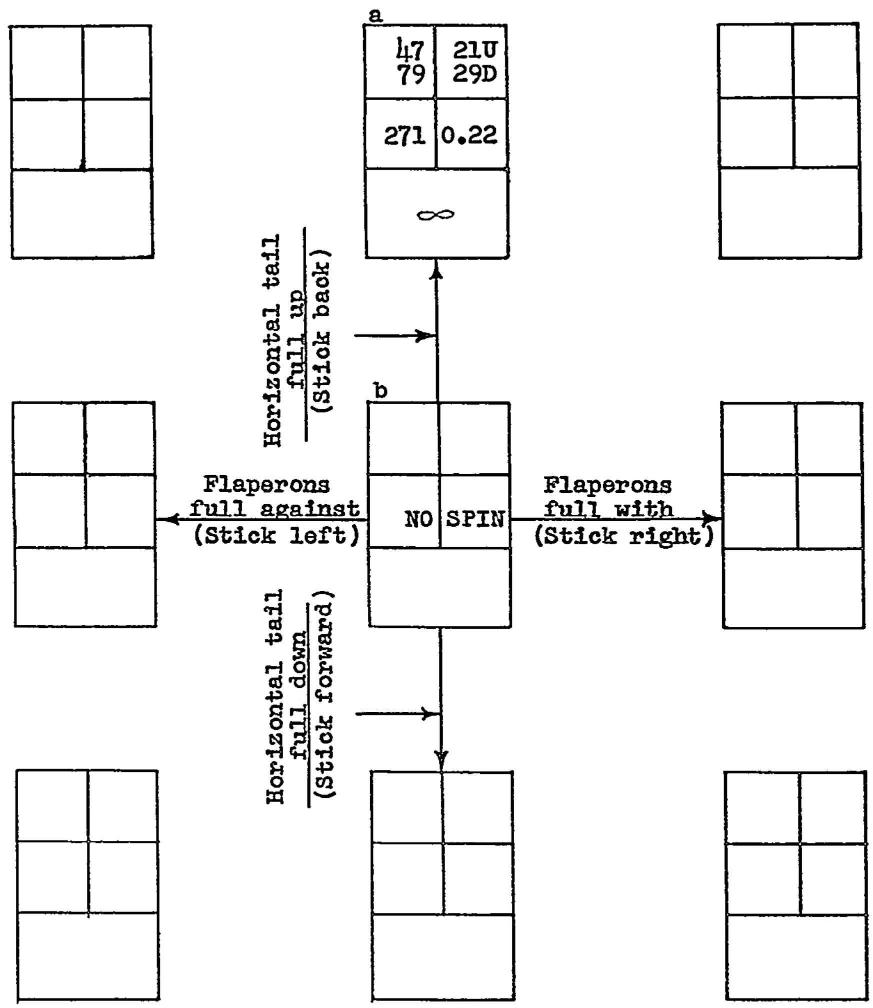


[a]Entered a glide.
[b]Spun for short duration (10 to 12 turns) before entering glide.
[c]Oscillatory spins, range of values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 10.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spins; recovery attempted by rapid full rudder reversal; angular momentum not simulated; maximum rudder deflection ±6°]



[a]Oscillatory spin, range of values given.

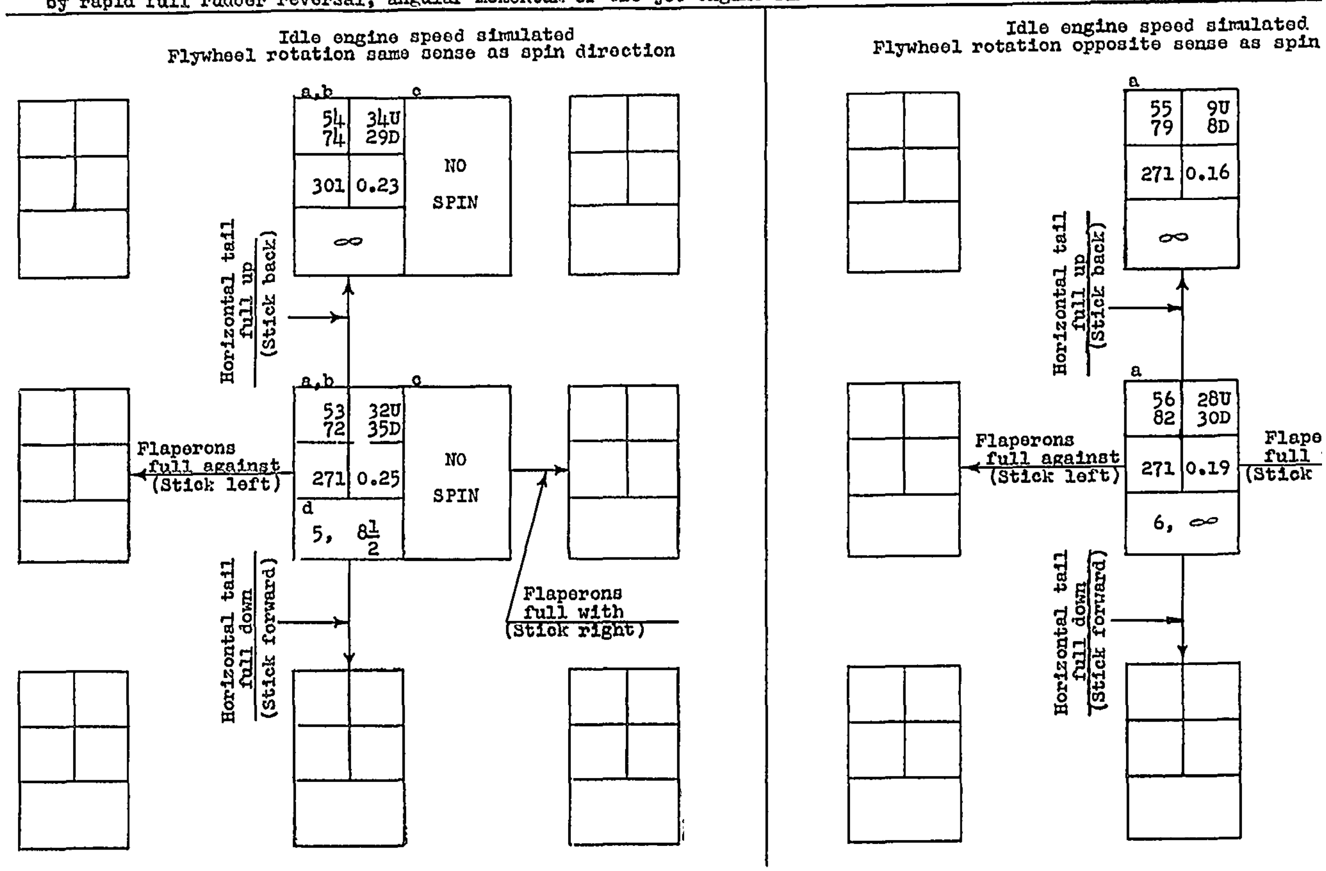
[b]Entered a dive.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 11.- RIGHT-ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/24-SCALE MODEL OF THE GRUMMAN F11F-1 AI

[Landing loading; slats retracted; recovery attempted from, and steady-spin data presented for, rudder full with spins; by rapid full rudder reversal; angular momentum of the jet engine simulated as indicated; maximum rudder deflection



[a]Oscillatory spin, range of values given.
[b]Spun for short duration, then model oscillated out of the spin and entered a glide.
[c]Entered a dive.
[d]Recovered in an inverted dive.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

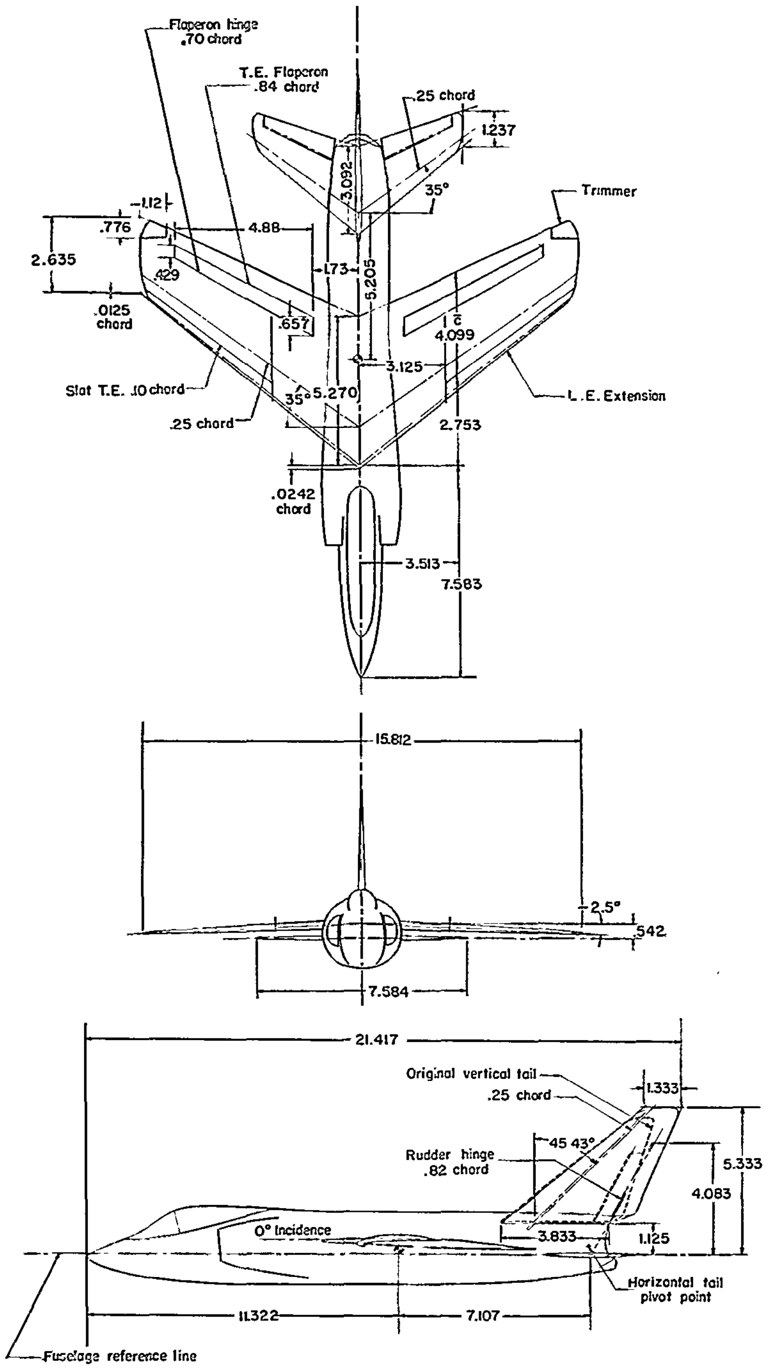
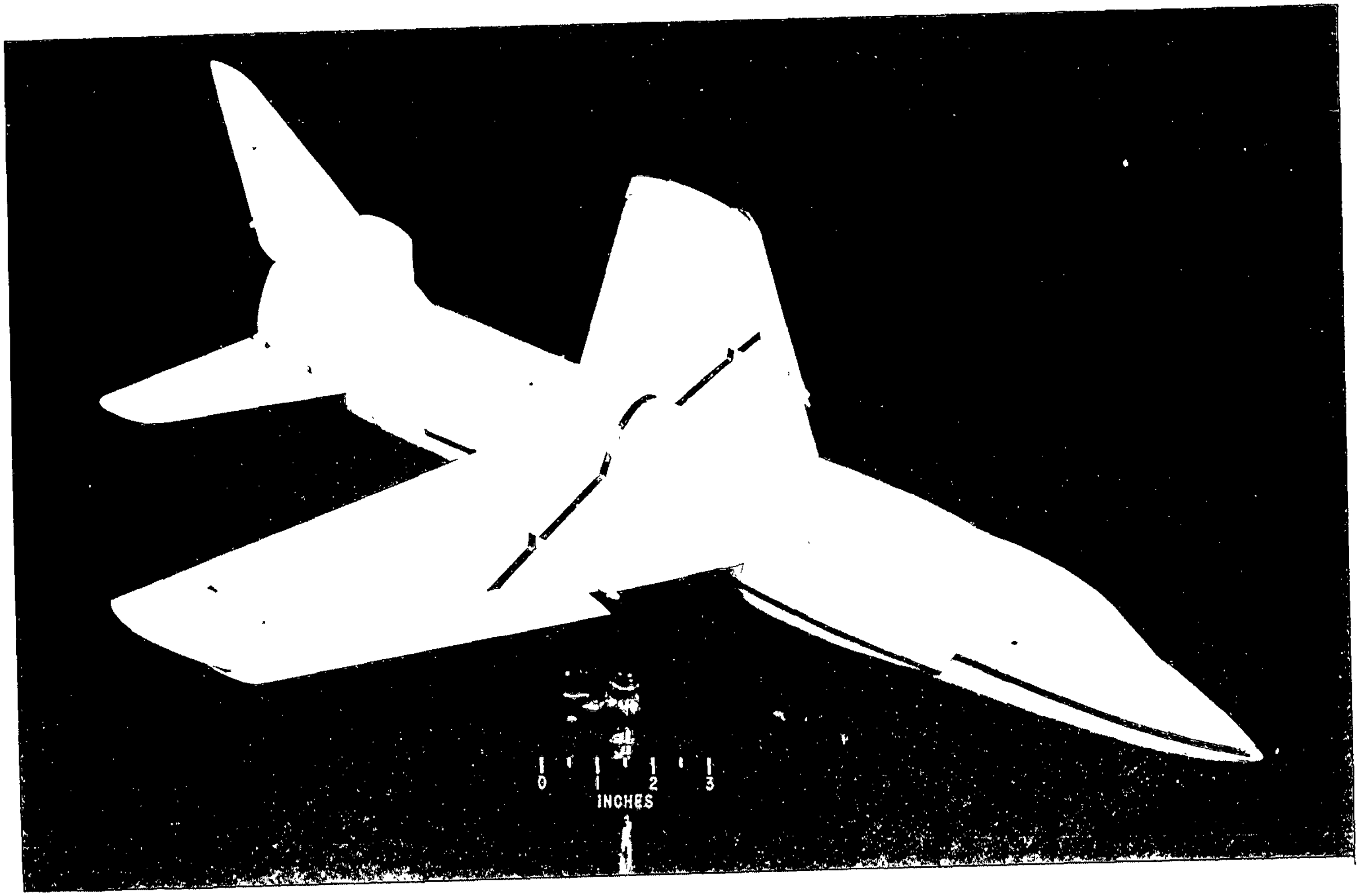


Figure 1.- Three-view drawing of the 1/24-scale model of the Grumman F11F-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values in inches. Center-of-gravity position shown is 24 percent mean aerodynamic chord.



L-84786.1

Figure 2.- Photograph of the 1/24-scale spin model of the Grumman F11F-1 airplane with leading-edge slats extended.

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Piloting Techniques	7.7

ABSTRACT

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/24-scale model to determine the spin and recovery characteristics of the Grumman F11F-1 airplane. Extension of canards near the nose of the airplane or deflecting the horizontal tail differentially with the spin was found to be necessary with rudder reversal in order to obtain satisfactory spin recoveries.

[redacted]